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Research Article

Investigation of Radiolysis Induced Dosimetric Parameters of a Synthetic Dye for Gamma Dosimetry

Muhammad Khawar Hayat[1,2*], Rabia Khaliq[1,2], Ramiza[1], Taqmeem Hussain[3], Inamul Haq[1, 4], Abdul Hanan Saeed[1], and Muhammad Imran Khan[1]

[1]Department of Physics, University of Agriculture, Faisalabad
[2]School Education Department (SED), Government of the Punjab, Pakistan
[3]Department of Physics, Government College University, Faisalabad
[4]Higher Education Department, Government of Punjab, Pakistan

Abstract: Present work deals with the study of radiation-induced dosimetric parameters of aqueous solutions of Sandalfix Orange C2RL (SO) dye within 0.1-100 kGy gamma dose range. A UV/VIS spectrophotometer was used for the spectrophotometric analysis of irradiated and un-irradiated sample solutions.Sample solutions were irradiated by Cs^{137}γ-ray source within 0.1-100 kGy dose range and sample solutions were analyzed in three different dose ranges i.e., 0.1-0.9kGy (low dosimetry), 1-9kGy (intermediate dosimetry) and 10-100 kGy (high dosimetry), respectively. The effect of gamma radiation on the response of co-factors of absorbance i.e., change in absorbance (ΔA) and relative absorbance (Ã) was discussed.The value of molar extinction coefficient was maximum at 430nm and decreased with respect to absorbed dose (D).

Keywords: Radiolysis, Molar extinction coefficient, Relative absorbance, Change in absorbance, Dosimetry, Gamma radiation, Sandalfix orange C2RL, SO dye

1. INTRODUCTION

Now-a-days the chances of exposure to Ionizing Radiations (IRs) have been increased. Therefore, radiation measurement is an active research area of present era. Radiation Dosimetry (RD) plays an important role in the quality control of radiation processing [1]. A quantitative study in RD requires information of the amount of energy absorbed by the IR. IR is a special type of advanced oxidation processes (AOPs) which can yield nearly equal amounts of oxidizing species (•OH and H_2O_2) and reducing species through water treatments [2]. Irradiation can change the chemical properties of a chemical dosimeter; which may respond linearly, exponentially or logarithmically etc. to IRs under appropriate conditions. Dyes either natural or artificially produced are being used to impact color as well as for dosimetric purposes like aqueous solutions [3-10]. Researchers have used different colors i.e., direct yellow 12 [4], alizarin yellow GG [2], sandalfix red C4BLN and sandalfix yellow CRL [8].

Dye dosimeters work on the principle of chemical dosimeters; and are being used for the estimation of absorbed dose of gamma radiation [11-15]. The absorbance (A) of the aqueous solutions of Sandalfix Orange C2RL (SO) dye was found to decrease linearly and logarithmically for low dosimetry (0.1-1 kGy) and high dosimetry (10-100 kGy) ranges, respectively. However, an exponential and logarithmic increase in %decoloration (%Đ) was observed within 0.1-1 and 10-100 kGy, respectively [11]. Absorption spectra of SO dye showed that the absorbance (A) of irradiated solutions was decreased with respect to absorbed dose (D). Mean absorbance (Ā) of irradiated sample solutions followed a linearly decreasing function with respect to absorbed dose (D) within low dosimetry range while logarithmically decreasing response of Ā was observed for both intermediate

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* Corresponding Author: Muhammas Khawar Hayat; mkhawar_uaf@yahoo.com

and high dosimetry ranges [12]. The decoloration (Đ) of aqueous solutions of congo red (CR) dye showed a linear relationship with absorbed dose [16].

Dye dosimetry is an area of interest for the researchers to produce eco-friendly and inexpensive dosimeters which have the capacity to work within wide dose range. The value of molar extinction coefficient for solutions is required in many scientific, engineering and chemical disciplines involving photon interactions [17].Calculating the molar extinction coefficient (ε) of material(s) is important in the field of radiation physics [18]. Sandalfix Orange C2RL (SO) dye is inexpensive and easily available in market. The proposed plan of this work is to investigate the radiation-induced dosimetric parameters of the aqueous solutions of SO dye within the selected dose range.

2. MATERIALS AND METHODS

The sample solutions of Sandalfix Orange C2RL (SO) dye (Molecular Weight: 1034.27 amu; Molecular Formula: $C_{31}H_{20}ClN_7Na_4O_{16}S_5$) were prepared by following the procedures as reported by Hayat et al., [11-12]. The prepared acidic sample solutions (having pH value 4, 5 and 6) were stored in dark. A UV-Visspectrophotometer *(Lambda 25 1.27, PerkinElmer, USA)* was used for the determination of characteristic wavelength (λ_{max}); absorbance (A) of all the sample solutions was determined at this λ_{max}. Cuvettes (path length of 1 cm) were used to keep the solutions in the object beam. Figure 1 shows the molecular structure of SO dye.

3. RESULTS AND DISCUSSION

Effect of IR on an exposed material depends upon the composition of that material and energy transferred by the incident photon.Water radiolysis causes the production of species i.e., hydrated electron, H_2O_2, H_2, OH^-, H^+ and •OH radical etc. The production of these primary species depends upon the linear energy transfer value of radiation [11]. The electrophilic attack by •OH radicals occurs at the carbon (C) atoms where the naphthalene ring and the azo group link up. This reaction leads to the destruction of the chromophore. So, the products formed do not have enough light absorption and consequently absorbance of the sample solutions decreases. The probability of partial or total saturation of N=N also exists in this reaction [19]. The absorbance (A) of SO is decreased with respect to absorbed dose (D) caused the increase in response of both co-factors of absorbance i.e.,change in absorbance (ΔA) and relative absorbance (Ã).

Response curves are obtained by plotting ΔA and Ã against absorbed dose (D). Change in absorbance (ΔA) can be calculated by using equation 1 [20].

$$\Delta A = A_0 - A_i \quad (1)$$

Where, A_0 and A_i represent the absorbance of un-irradiated and irradiated sample solution,

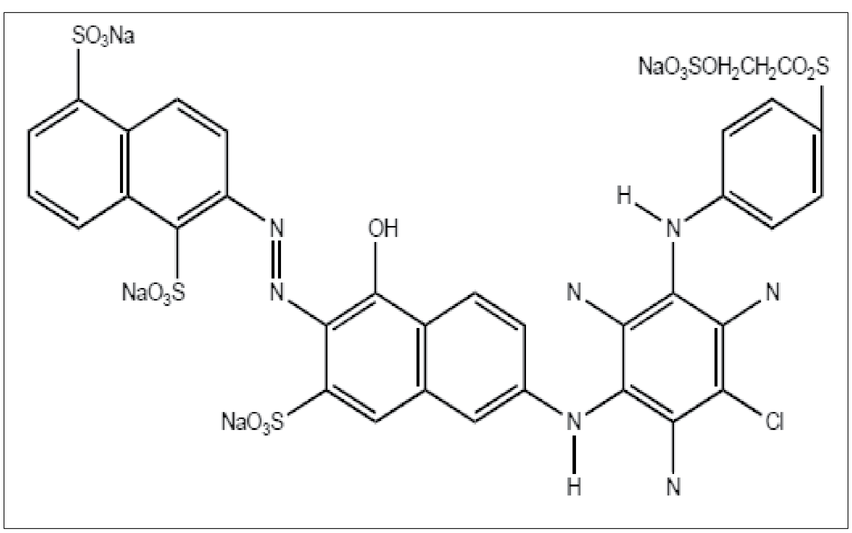

Fig. 1. Structure diagram of SO dye

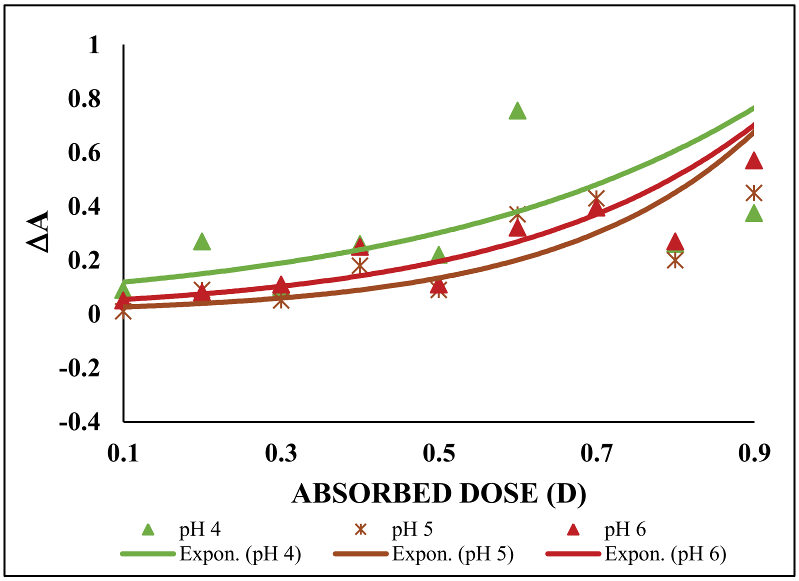

Fig. 2. Response of change in absorbance (ΔA)within 0.1-1 kGy dose range

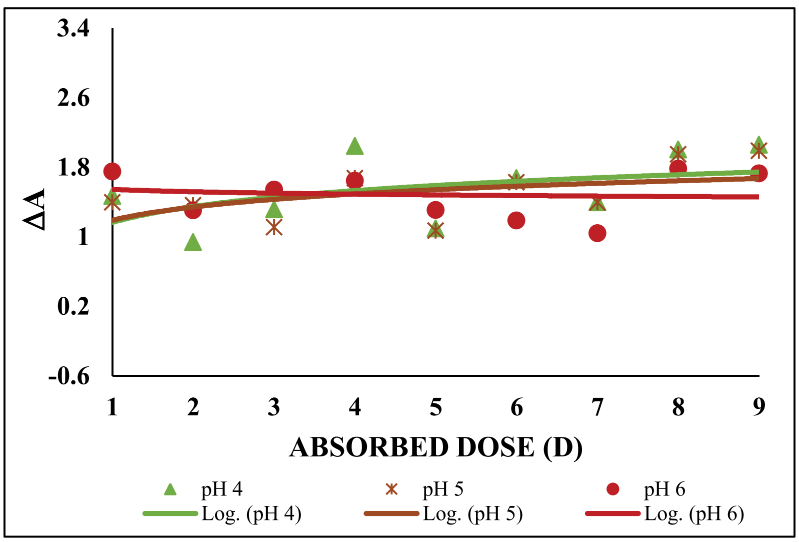

Fig. 3. Response ofchange in absorbance (ΔA)within 1-10 kGy dose range

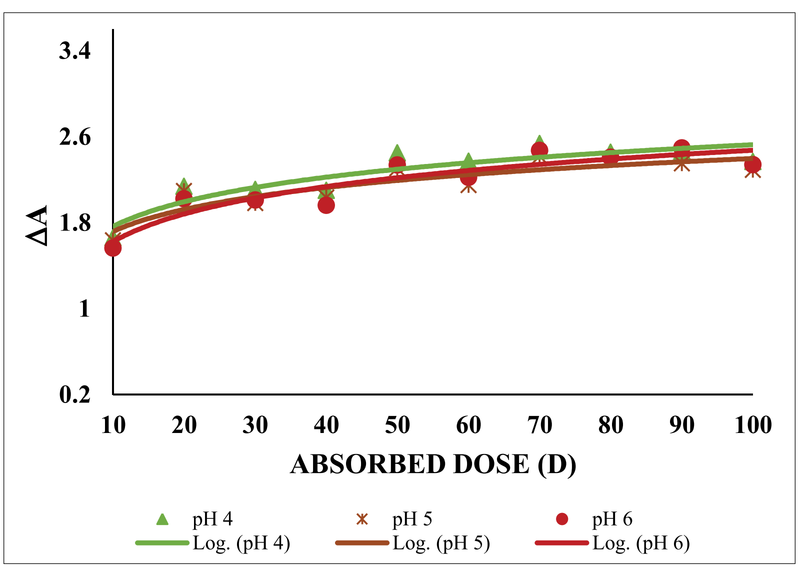

Fig. 4. Response of change in absorbance (ΔA) within 10-100 kGy dose range

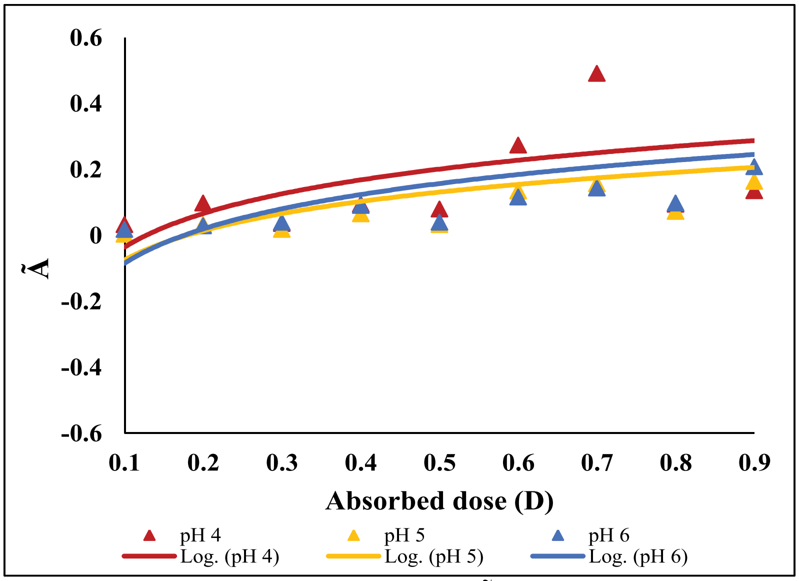

Fig. 5. Response of relative absorbance (Ã) within 0.1-1 kGy dose range

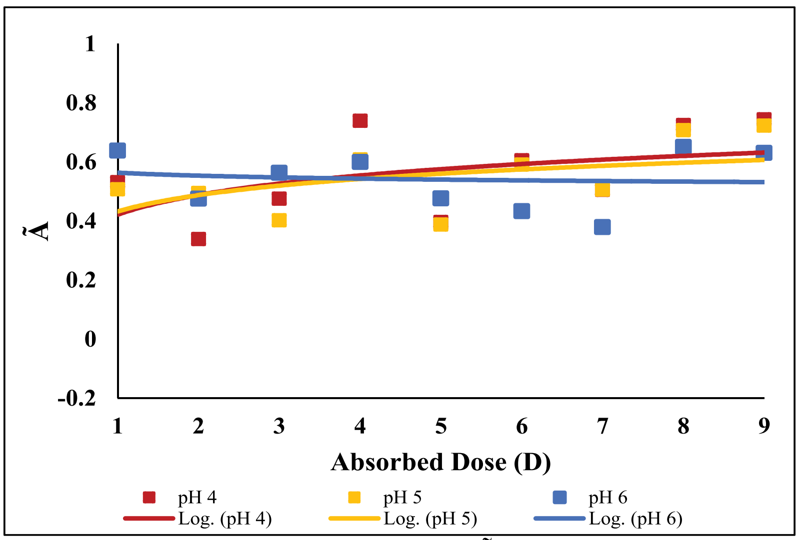

Fig. 6. Response of relative absorbance (Ã) within 1-10 kGy dose range

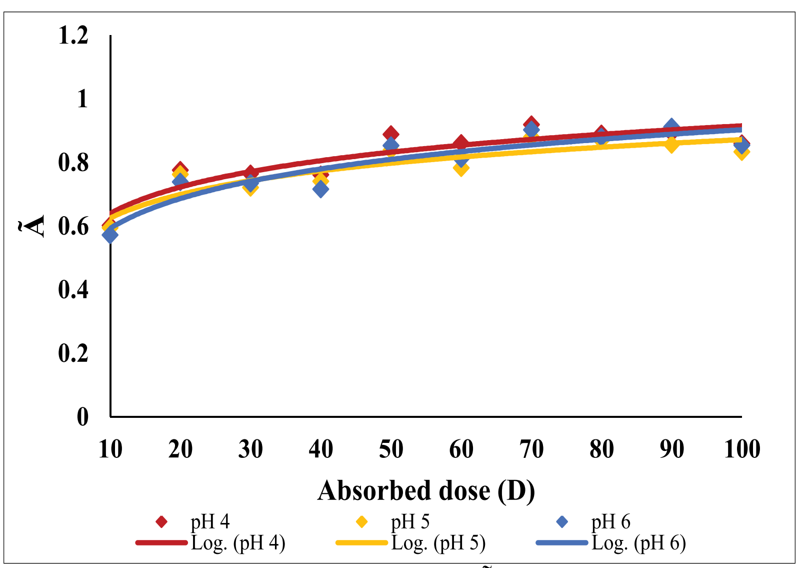

Fig. 7. Response of relative absorbance (Ã) within 10-100 kGy dose range

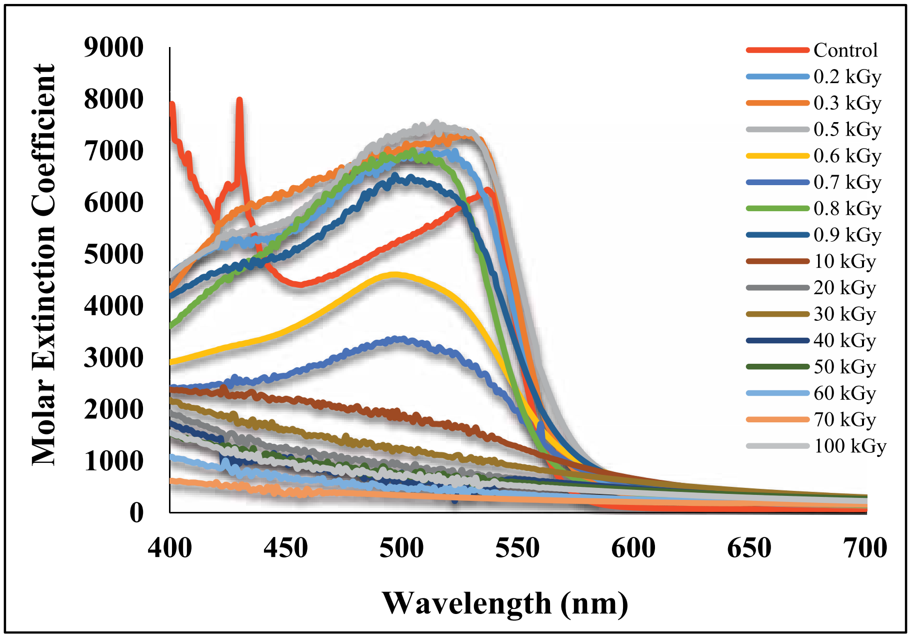

Fig. 8. Value of molar extinction coefficient (ε) of control and irradiated sample solution versus wavelength (nm)

respectively. Figure 2, 3 & 4 illustrate the change in absorbance (ΔA) of irradiated acidic sample solutions of SO dye with respect to absorbed dose (D) at characteristic wavelength (nm) i.e., 430 nm.

The ΔA is increased exponentially with respect to absorbed dose (D) within low dosimetry; while in both intermediate and high dosimetry ranges, the ΔA is increased logarithmically with respect to absorbed dose (D). Results give the evidence of photo-degradation of SO dye and the formation of defects and clusters in the material upon irradiation. Sensitivity to incident gamma photons is decreased with decrease in initial absorbance (A) [1]; so increase in ΔA is observed. The relative absorbance (Ã) of the sample solution can be calculated by using equation 2[21].

$$\tilde{A} = (\Delta A/A_0)_{430} \quad (2)$$

Where,ΔA and A_0 represent the change in absorbance and absorbance of un-irradiated sample solutions, respectively, at characteristic peak (λ_{max}=430 nm).

Figures 5, 6 and 7 represent the relative absorbance (Ã)of irradiated acidic sample solutions of SO dye within low, intermediate and high dosimetry ranges, respectively, which show the signs of dye degradation at different irradiation doses. The response of Ã tends to follow a good logarithmic function with respect to absorbed dose (D) as the dose increases from low to high dosimetry range. The value of Ã is found to increase with respect to absorbed dose (D)and follows a logarithmic function within 0.1-100 kGy dose range.

The probability of a medium (solution) to absorb a photon is directly proportional to the concentration of the solute in the solution and to the thickness of the sample solution as given in equation 3 (Beer-Lambert law).

$$A = \varepsilon c l \quad (3)$$

$$\varepsilon = A/cl \quad (4)$$

Where, A is absorbance, l is the path length of Cuvette, c is the concentration of solute and ε is the molar extinction coefficient. The value of *"ε"* depends upon the wavelength of the incident radiation; and is maximum where the absorption is most intense [17]. Figure 8 represents the value of molar extinction coefficient (ε) with respect to wavelength (nm). For control sample solution; the value of *"ε"* is maximum at 430 nm because the absorption is most intense at this wavelength. However, the value of *"ε"* is decreased with respect to absorbed dose (D)for irradiated sample solutions

Table 1. Value of molar extinction coefficient (ε) within low dosime

Dose (kGy)	Molar Extinction Coefficient		
	pH4	pH5	pH6
0.1	5286.89	5348.36	5327.87
0.2	4959.02	5245.90	5204.92
0.3	5102.46	5389.34	5512.29
0.4	4979.51	5122.95	4938.52
0.5	5081.97	5409.84	5614.75
0.6	4040.98	4610.66	4877.05
0.7	2799.18	4764.34	4938.52
0.8	4907.79	5081.97	4815.57
0.9	4774.59	4877.05	4436.48

Table 2. Value of molar extinction coefficient (ε) within intermediate dosime

Dose (kGy)	Molar Extinction Coefficient		
	pH4	pH5	pH6
1	2688.52	2926.23	2188.52
2	3606.56	2725.41	2922.13
3	2991.80	3520.49	2594.26
4	1272.54	1887.30	1926.23
5	3532.79	3356.56	2938.52
6	2159.84	2311.48	3204.92
7	2836.07	2758.20	3200.82
8	1778.69	1631.15	2094.26
9	1331.97	1485.66	2397.54

Table 3 Value of molar extinction coefficient (ε) within high dosimetry

Dose (kGy)	Molar Extinction Coefficient		
	pH4	pH5	pH6
10	2397.54	2327.87	2430.33
20	1254.10	1432.38	1479.51
30	1321.72	1575.82	1538.93
40	1411.89	1467.21	1502.05
50	788.93	971.31	823.77
60	993.85	1120.90	975.41
70	807.38	973.36	907.79
80	834.02	852.46	1407.79
90	807.38	782.79	676.23
100	956.97	956.97	866.80

of SO dye. The results are in agreement with the Beer's law and the statement of Singh et al., (2002) [18]. Tables 1, 2 and 3 give the value of *"ε"* within low, intermediate and high dosimetry conditions, respectively.

4. CONCLUSION

The aqueous solutions of SO dye showed sensitivity to gamma radiation. It was found that, except low dosimetry range (0.1-0.9kGy), both co-factors of absorbance i.e., change in absorbance (ΔA) and relative absorbance (Ã) followed the logarithmic function with respect to absorbed dose (D). The response of ΔA followed an exponentially increasing function with respect to absorbed dose (D) within 0.1-0.9kGy dose range while a logarithmic relationship was found between ΔA and absorbed dose (D) for both intermediate and high dosimetry ranges. Response of Ã followed a logarithmically increasing function within 0.1-100 kGy dose range. The value of molar extinction coefficient *"ε"* was decreased with respect to absorbed dose (D). The investigation of dosimetric parameter revealed the sensitivity of SO dye towards gamma radiation and its degradation upon irradiation.

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